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***published in***

American Journal Sports Medicine  
2002

***DOI (link to publisher)***

[10.1177/03635465020300012101](https://doi.org/10.1177/03635465020300012101)

***document version***

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***citation for published version (APA)***

Tol, J. L., Slim, E., van Soest, A. J., & van Dijk, C. N. (2002). The relationship of the kicking action in soccer and anterior ankle impingement syndrome: a biomechanical analysis. *American Journal Sports Medicine*, 30, 45-50.  
<https://doi.org/10.1177/03635465020300012101>

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*Am J Sports Med* 2002 30: 45

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# The Relationship of the Kicking Action in Soccer and Anterior Ankle Impingement Syndrome

## A Biomechanical Analysis

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### ABSTRACT

Two different hypotheses have been advanced to explain the formation of talotibial osteophytes in the anterior ankle impingement syndrome. We investigated how frequently hyperplantar flexion occurs during kicking and whether the site of impact of the ball coincides with the reported location of the osteophytes. We also measured the magnitude of the impact force. We studied 150 kicking actions performed by 15 elite soccer players by using mobile sensors and high-speed video. In 39% of the kicking actions, the plantar flexion angle exceeded the maximum static plantar flexion angle. Ball impact was predominantly made with the antero-medial aspect of the foot and ankle, with impact between the ball and the base of the first metatarsal bone in 89% of the kicking actions and between the ball and the anterior part of the medial malleolus in 76%. Postimpact ball velocity averaged 24.6 m/s, with a corresponding average contact force of 1025 N. Hyperplantar flexion was reached in only the minority of the kicking actions. The data on impact location and impact force support the hypothesis that spur formation in anterior ankle impingement syndrome is related to recurrent ball impact, which can be regarded as repetitive microtrauma to the anteromedial aspect of the ankle.

Formation of talotibial osteophytes at the anterior part of the ankle joint is a common cause of chronic anterior ankle pain.<sup>1–4,7–9,11–17,19</sup> The presence of osteophytes has been reported in as many as 60% of professional soccer players (percentage based on 80 players).<sup>8</sup> Morris<sup>11</sup> (1943), and later McMurray<sup>10</sup> (1950), named the condition “athlete’s ankle” or “footballer’s ankle” and prescribed the treatment. In subsequent studies the term has been replaced by “anterior ankle impingement syndrome.”<sup>3,13–17,20</sup> The exact cause of the formation of impinging talotibial osteophytes is not fully understood.

One hypothesis assumes that recurrent traction on the joint capsule during maximal plantar flexion movements of the foot, as is assumed to occur during kicking actions in soccer, is the essential cause, resulting in traction spurs.<sup>1,2,8,10</sup> In a more recent hypothesis it has been suggested that formation of osteophytes in the ankle is related to direct damage to the rim of the anterior ankle cartilage in combination with recurrent microtrauma, such as is caused by direct impact of the soccer ball on the anterior ankle region.<sup>20</sup> The potential risk of the impact of a soccer ball has been described by several authors.<sup>5,6,9,18</sup> Direct macrotrauma is observed in the majority of patients with supination traumas.<sup>19</sup> Subsequent direct recurrent microtrauma by repetitive kicking actions will induce inflammation, the development of scar tissue, calcification, and, subsequently, spur formation.<sup>20</sup> This hypothesis involves the assumption that during the kicking action there is direct impact of the ball on the anterior ankle region and that the magnitude of the impact forces is potentially harmful.

Even though these two hypotheses are widely cited, experimental support for either is scarce. The aim of this study was to investigate how frequently hyperplantar

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No author or related institution has received any financial benefit from research in this study.

flexion occurs during kicking, whether the site of impact of the ball coincides with the location of the osteophytes, and whether the magnitude of the impact force is potentially harmful. In particular, we gathered data regarding range of motion, impact location, and impact force.

## MATERIALS AND METHODS

### Experimental Setting

The experiment was performed in an indoor exercise laboratory with an artificial turf surface. The subjects were instructed to kick a soccer ball (434.8 g, 700 g/cm<sup>2</sup>; type GEO 850, Nike, Beaverton, Oregon) at a goal (length, 7.3 meters; height, 2.4 meters) located at 11.0 meters distance. The experimental setting was shielded by a safety net. A small ramp (height, 133 cm; length, 257 cm), located between the goal and at a distance of 6.2 meters from the kick-off place at an angle of 55°, was used for rolling the ball with a velocity of 2.2 m/s toward the kick-off place.

Before the experiment, all subjects followed a warm-up protocol consisting of 15 minutes of cycling on an ergometer (type GIH Monarch, Stockholm, Sweden) with an increasing load (75 to 200 watts) and 15 minutes of familiarization trials with the experimental setting. After this warm-up period, the static active plantar flexion of the subject's ankle was measured with the subject seated and the sole of his foot on the ground (horizontal reference). The fibular head and the lateral malleolus were marked with white adhesive markers. A digital camera (type MVC-FD7, Sony Digital, Tokyo, Japan) was positioned perpendicularly at a distance of 1.5 meters from the subject. Subjects were instructed to actively plantar flex their foot maximally. The foot was then photographed. On the photograph that was later printed, lines were drawn between the markers and the horizontal floor to create intersecting lines that could be measured by a goniometer. The measurements were expressed in degrees of plantar flexion.

A series of 10 kicks in which the ball reached the goal was registered for each subject. Five kicks of a stationary ball were followed by five kicks of a ball rolling toward the kick-off place. The subjects were instructed to perform each kick at maximal effort. After each trial, feedback was provided with regard to the velocity of the ball. The choice of approach was free.

### Subjects

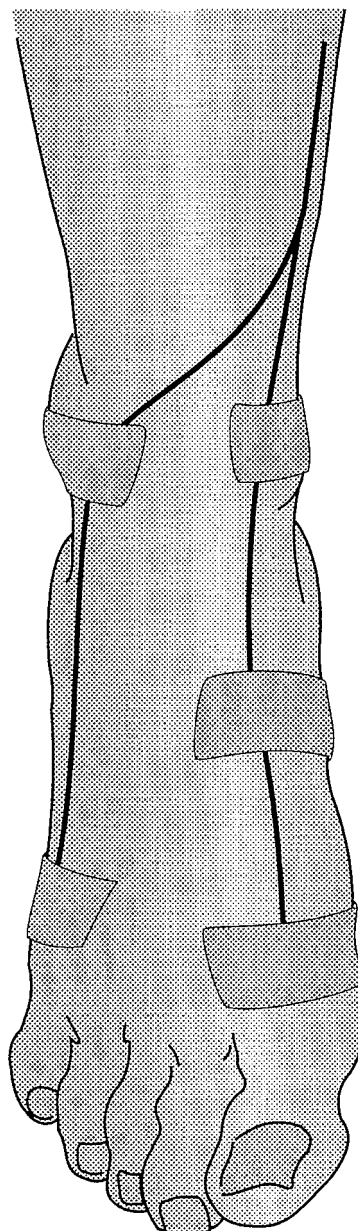
Fifteen right-foot dominant highly active amateur soccer players with an average age of 27.4 years (range, 19 to 35) took part in the experiment. All subjects were men and had at least 10 years' experience playing soccer (average, 18.4 years).

### Apparatus

The location of the impact of the ball to the foot or ankle was determined by five contact sensors, with a dimension

of 2.0 × 1.5 cm (constructed by the Department of Medical Technology Development, Academic Medical Center). The sensors were placed, using adhesive tape, over the anterior side of the medial malleolus, the base of the first metatarsal bone, the head of the first metatarsal bone, the base of the fifth metatarsal bone, and the anterior side of the lateral malleolus (Fig. 1). Impact on the time-independent sensors generated an output voltage that was radio-graphically transmitted to a five-channel momentary-mode receiver (type FMDH4-XXX, Farnell, Leeds, United Kingdom) and saved onto a personal computer.

Planar kinematics were studied using a high-speed video camera (SpeedCam 512 Lite; Weinberger, Karlsruhe, Ger-



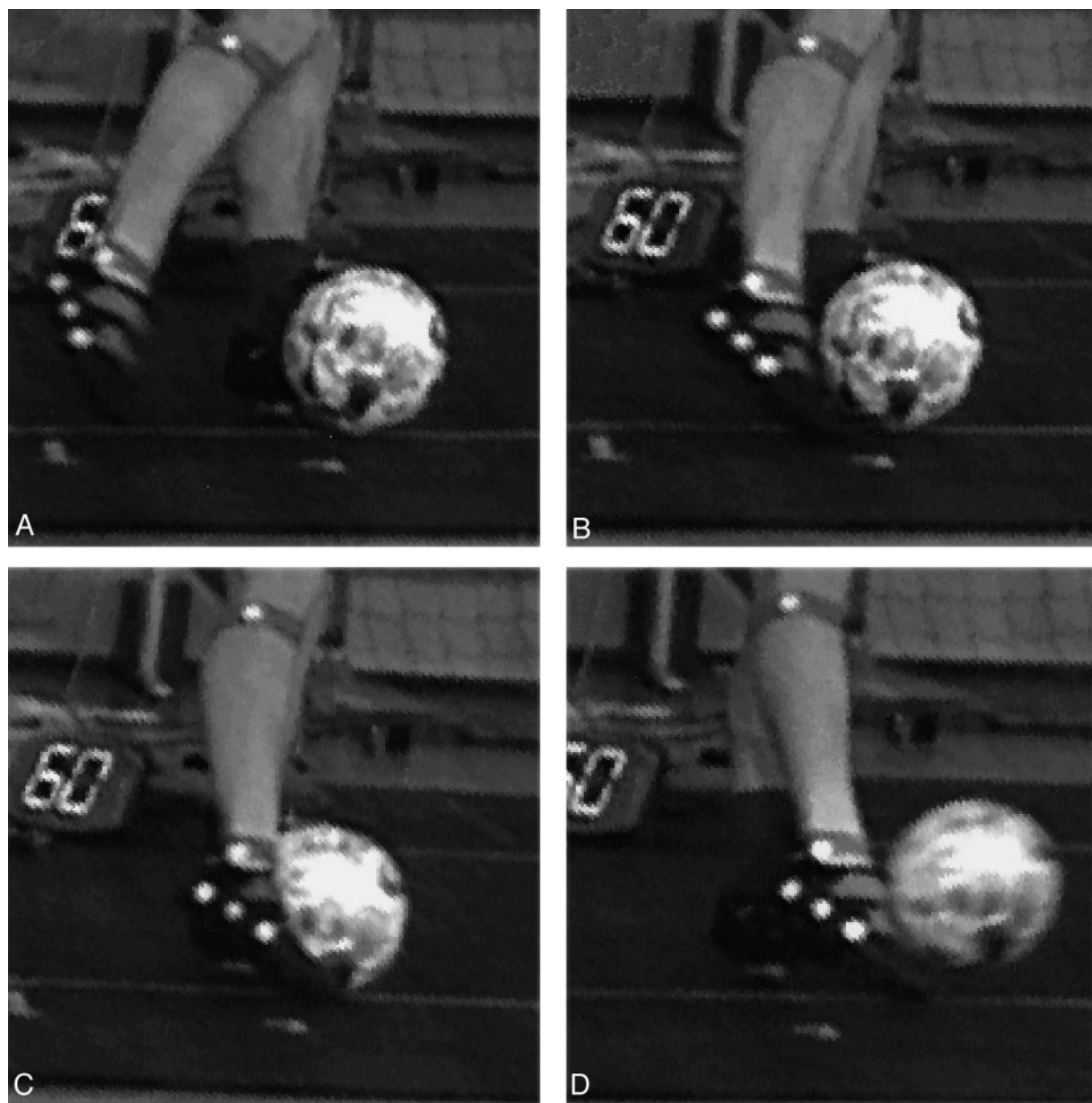
**Figure 1.** Location of contact sensors on the foot.

many) running at a frequency of 1 kHz. Retroreflective markers were placed on the fibular head, the lateral malleolus, the calcaneus, the base of the fifth metatarsal bone, and the head of the fifth metatarsal bone (Fig. 2). The camera was set on a tripod and was positioned at right angles to the plane of the kick-off place (distance, 2.5 meters; height, 0.3 meters). Twenty 100-watt lights were placed parallel to the camera to optimize contrast. The high-speed video data with chronologic codes were temporarily stored in the computer memory during the registration and subsequently recorded on videotapes. A conversion factor for changing film distances into real-life measurements was determined by filming a reference frame of known dimension in the plane of movement.

Data from the videotapes were digitized, and two-dimensional marker coordinates were obtained semiautomatically with use of Vidiplus (software package developed at the Faculty of Movement Sciences, Amsterdam).

#### Data Analysis

The results of the impact-area measurement from each sensor were analyzed with Excel software (Microsoft Corp., Redmond, Washington). The postimpact velocity of the ball, the angular displacement of the ankle, the impact duration, and the impact force were calculated from the high-speed video data.



**Figure 2.** Images observed with the high-speed video camera (1000 frames/sec). Image sequences of the preimpact (A), impact (B and C), and postimpact (D) processes during the kicking action.



The horizontal and vertical velocity of the ball during the first 0.01 seconds (10 frames) after the impact were calculated from the position of the ball in these frames. The angular displacement of the ankle was calculated from the position data of the markers on the subject's leg and foot. The angle between the lines formed by markers 1 to 2 and 3 to 4 to 5 was calculated (MATLAB 5.0; The Math Works, Inc., Natick, Massachusetts) and expressed in degrees of plantar flexion. The impact duration of the ball was obtained from the number of frames in which ball-to-foot contact was observed.

The change in the momentum of the ball ( $p$ ) was calculated from the ball mass ( $m_b$ ) and the velocity of the ball before ( $V_{pre}$ ) and after ( $V_{post}$ ) impact according to the following equation:  $p = m_b \cdot (v_{post} - v_{pre})$ . Because the time integral of the force on the ball equals the change of ball momentum, the average impact force ( $F_{avg}$ ), recorded in newtons, could be estimated from measured quantities:  $F_{avg} = m_b \cdot (v_{post} - v_{pre}) / \Delta t$ , where  $\Delta t$  is the impact time. Note that the contribution of gravity to  $F_{avg}$  was neglected.

Differences in the velocity of the ball between the two kicking procedures were assessed with the Wilcoxon matched-pairs signed rank test. The Spearman correlation coefficient between the angular displacement and the velocity of the ball was calculated. The statistical significance level was set at 0.05.

## RESULTS

### Location of Ball Impact

The distribution of the location of the impact between the ball and the mobile sensors on the foot and the ankle is given in Table 1. Of the 150 attempts, the average number of activated sensors was 2.4.

### Velocity of the Ball

The average velocity of the ball in the 150 kicking actions was 24.6 m/s (range, 18.9 to 29.8). The horizontal and vertical velocity were 24.3 m/s and 3.6 m/s, respectively. The average ball velocity in the stationary-ball procedure was 24.3 m/s (range, 19.8 to 28.5), the horizontal velocity was 24.0 m/s, and the vertical velocity was 3.6 m/s. For the rolling-ball procedure, these figures were 24.9 m/s (range, 18.9 to 29.8), 24.7 m/s, and 3.6 m/s, respectively. There was no statistically significant difference in the postim-

pect velocity between the rolling-ball procedure and the stationary-ball procedure. The results of both procedures were therefore combined.

### Angular Displacement

The maximal static active plantar flexion, averaged over all subjects, was 46.8° (range, 40.0° to 51.0°). During the experiment, the average degree of plantar flexion angle changed from 26.1° just before impact to 47.6° (range, 26.7° to 60.8°) at the end of the ball impact. In 58 of the 150 kicking attempts (39%), the maximal plantar flexion exceeded the subject's maximal static plantar flexion. In 6 of the 15 subjects, the average plantar flexion angle during the kicking action exceeded the statically measured maximal plantar flexion angle (Fig. 3). No correlation was found between the velocity of the ball and the angular displacement ( $r_s = 0.273$ ).

### Impact Time, Force, and Impulse

The average duration of the impact of the foot or the ankle and the soccer ball was 10.7 msec (range, 8 to 17). The average force and impulse of impact was found to be 1025 N and 11.0 N/s, respectively.

## DISCUSSION

Two hypotheses have been suggested for the cause of talotibial osteophyte formation in soccer players. The first is that recurrent hyperplantar flexion of the foot, inducing traction on the anterior joint capsule, is the essential cause, resulting in traction spurs.<sup>1,2,8,10</sup> The second is that formation of osteophytes in the ankle is related to direct trauma to the rim of the ankle cartilage caused by compressive forces occurring during the impact of ball to foot. In this study, we analyzed the degree of hyperplantar flexion, the impact location, and the average impact force during the kicking action to test these hypotheses.

There are methodologic pitfalls and limitations to this

TABLE 1  
Distribution of the Location of Ball Impact on the Contact Sensors on the Foot and Ankle in 150 Kicking Attempts

Location of ball impact	Number of impacts	Percentage of total attempts
Medial malleolus	114	76
Base 1st metatarsal	134	89
Head 1st metatarsal	94	62
Base 5th metatarsal	6	4
Lateral malleolus	12	8

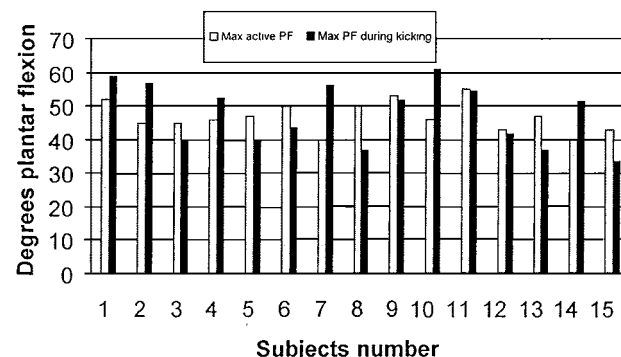


Figure 3. Maximal static active plantar flexion measured with a goniometer (Max active PF) and average plantar flexion calculated from the high-speed analysis during 150 kicking actions (Max PF during kicking) in 15 subjects.

study. First, the methods used for measurement of static active plantar flexion and of plantar flexion during kicking were slightly different. In the static condition, it was assumed that the sole of the foot was aligned with the floor. During the kicking action, the orientation of the sole of the foot was calculated from three markers on the soccer shoe. Small variations in the placement of the markers on the shoe and displacement of the foot in the shoe could have influenced the calculated degree of plantar flexion.

The contact sensors, which were placed on five anatomic landmarks, were used to register the ball-to-foot or ball-to-ankle impact location. The average impact force was calculated indirectly from the high-speed video data to give an impression of the potential risk of high-impact forces. Damage to anatomic structures is related to the degree of pressure. Direct measurements of the pressure distribution by pressure sensors would have given a more accurate reproduction of the pressure figures. However, such pressure sensors, which would have to quantify pressure figures in a very short impact period (<10.0 msec) were not available and are not described in the literature.

The results of the high-speed video analysis showed that plantar flexion increased during ball-to-foot impact. In 39% of the kicking actions, the plantar flexion angle exceeded the maximum static angle. Thus, in these kicking actions, extensive repetitive strain on the anterior joint capsule does occur. This result supports the hypothesis that anterior osteophytes (spurs) can be the result of traction.<sup>1,2,8,10</sup>

However, morphologic data are not fully in support of this hypothesis. It has been reported on the basis of observation during surgical procedures that genuine traction spurs located exactly near the attachment of the anterior joint capsule are found only in a minority of cases.<sup>3,20</sup> In most cases the osteophytes are situated at the articular margin of the anterior ankle joint. In normal anatomy, the lower surface of the anterior tibia and the anterior part of the medial malleolus are covered with cartilage. It is this nonweightbearing cartilage rim that undergoes the osteophytic transformation. These osteophytes are located 5 to 8 mm distal to the capsular attachment and are therefore unlikely to be the result of repetitive strain on the joint capsule.

According to the hypothesis of recurrent direct trauma to the ankle cartilage rim, ball impact should occur in the area where osteophytes are found, and impact forces should be high enough to be potentially harmful. Analysis of the location of ball impact during the kicking action showed that impact with the ball was predominantly at the anteromedial aspect of the foot and ankle. In 89% and 76% of the kicking actions, there was impact between the ball and the base of the first metatarsal bone and the anterior part of the medial malleolus, respectively.

In the present experiment, the calculated average values of impact time, force, and impulse were 10.7 m/s, 1025 N, and 11.0 N/s, respectively. The impact force represents the average net force of impact. Thus, this figure represents a lower limit of the peak impact force. The peak impact force depends on the shape of the force-time curve. If we assume that the impact force-time curve can be

approximated by a half sine wave, the peak impact force is found to be the average impact force multiplied by  $\pi/2$ , yielding 1610 N. The impact forces that occur during ball-to-foot impact are capable of damaging anatomic structures. The impacts during kicking actions can act as repetitive trauma to the anterior rim of cartilage of the medial malleolus. Except for a thin subcutaneous layer, parts of the anterior cartilage rim are covered only by skin. Recurrent trauma due to repetitive kicking might induce inflammation, development of scar tissue, calcification, and subsequent spur formation. In cases where local cartilage damage is already present, due to supination or direct trauma, repetitive ball kicking can be regarded as an additional factor in the development of the footballer's ankle.<sup>10,19,20</sup>

In conclusion, maximal plantar flexion was reached in only a minority of the kicking actions. The majority of the talotibial osteophytes are not located at the capsular attachment. The hypothesis of formation of talotibial osteophytes due to recurrent microtrauma to the joint capsule leading to the formation of traction spurs is therefore plausible only in the minority of cases. However, the data on impact location and impact force reported in this study do support the hypothesis that anterior ankle impingement syndrome is related to the occurrence of direct damage to the ankle cartilage rim, with subsequent reactive spur formation.

## ACKNOWLEDGMENT

The authors are indebted to Reinka B.V., Breda, the Netherlands, for providing their high-speed video system and assistance during the experiment.

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